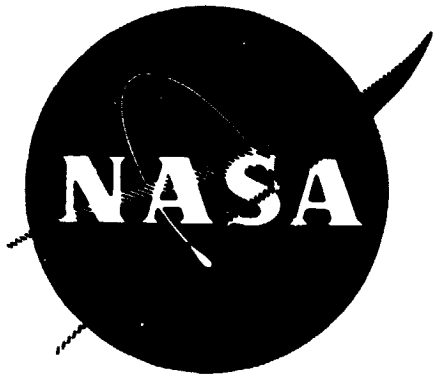

INITIAL EVALUATION TESTS
of
GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR NICKEL-CADIUM SPACECRAFT CELLS
for the
GOES-D, E and F SATELLITE PROGRAM

prepared for

GODDARD SPACE FLIGHT CENTER

Contract S-57075AG

WEAPONS QUALITY ENGINEERING CENTER

NWSC Crane, Indiana

DEPARTMENT OF THE NAVY
NAVAL WEAPONS SUPPORT CENTER
WEAPONS QUALITY ENGINEERING CENTER
CRANE, INDIANA 47522

EVALUATION PROGRAM
FOR
SECONDARY SPACECRAFT CELLS

INITIAL EVALUATION TESTS
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6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
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WQEC/C 79-224

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Enclosure (1)

REPORT BRIEF
INITIAL EVALUATION TESTS
OF
GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
GOES-D, E AND F SATELLITE PROGRAM

Ref: (a) NASA PURCHASE ORDER S-57075AG
(b) Initial Evaluation Test Procedure for Nickel-Cadmium Sealed Space Cells: NAD 3053-TP324; 10 Apr 1973

I. TEST ASSIGNMENT BRIEF

A. The purpose of this evaluation test program is to insure that all cells put into the life cycle program are of high quality by the screening of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open-circuit voltage above 1.150 volts during the internal short test.

B. The sixteen cells were provided by the National Aeronautics and Space Administration, Goddard Space Flight Center (GSFC), to NAVWPNSUPPCEN Crane for evaluation on real time and accelerated synchronous orbits. The cells were purchased by GSFC, under NASA Purchase Order Numbers S-53504-B and S-614478 from the General Electric Company. Two additional cells (one with swaglok fitting) will be supplied by Hughes Aircraft Company (HAC) for evaluation on the real time synchronous orbit. All the cells were manufactured at the same time and from the same materials as the first lot of cells manufactured for HAC for the GOES-D, E and F Satellite Program. These cells were manufactured in accordance with "Product Specification Hermetically Sealed Nickel-Cadmium Battery Cell-6AH-GOES," Hughes #PS 31999-013, Revision D. The two cells supplied by HAC were subjected to acceptance testing at HAC in accordance with "Acceptance Test Specification Sealed Nickel-Cadmium Battery Cell HS-371," TS 31999-021, prior to shipment to Crane. The cells were identified by the manufacturer's catalog number 42B006AB58-G1 and HAC's part number 259300. (See Appendix I for detailed cell description.) These cells are rated at 6.0 ampere-hours and contain single ceramic seals on the positive terminals. Testing was funded in accordance with reference (a).

C. Test limits specify those values at which a cell is to be terminated from charge or discharge. Requirements are referenced to as normally expected values based on past performance of aerospace nickel-cadmium cells with demonstrated life characteristics. A requirement does not constitute a limit for discontinuance from test.

II. SUMMARY OF RESULTS

A. Measurement of the cell containers, following test, indicated an average increase of .005 inches in the plate stack thickness.

B. Average end-of-charge voltages and capacity output in ampere-hours (ah) were as follows:

Charge	Volts	ah Out
C/20 for 48 hrs @ 25° C	1.444	7.4
C/10 for 24 hrs @ 25° C	1.455	7.1
C/10 for 24 hrs @ 20° C	1.460	6.8
C/10 for 24 hrs @ 20° C*	1.458	6.0
C/40 for 20 hrs @ 20° C**	1.374	2.3
C/20 for 60 hrs @ 0° C	1.491	6.9
C/10 for 24 hrs @ 35° C	1.419	7.2

*Charge retention test
**Charge efficiency test, 3.0 ah input

C. All cells exceeded the voltage requirement of 1.52 volts during the 0° C overcharge test although their end-of-charge voltages were below 1.50 volts. Their peak voltages were 1.522 to 1.534 volts.

D. The average cell voltage at the end of 1 week open-circuit-stand, during the charge retention test, was 1.312 volts.

E. The 24-hour average cell voltage following the 16-hour shunt period, during the internal short test, was 1.240 volts.

III. RECOMMENDATIONS

A. Manufacturing processes and controls should be such to prevent swelling of the plate stack, thereby preventing cell case distortion.

B. Cells should be manufactured with double ceramic seals.

C. It was recommended that these cells be placed on real time and accelerated synchronous orbit life tests.

D. In August 1979, one pack (227D) was placed in the synchronous sunlight mode prior to beginning its first eclipse period in October 1979. Two other packs (227E and 227F) began their first accelerated synchronous eclipse periods in August 1979.

RESULTS OF INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE GOES-D, E AND F SATELLITE PROGRAM

I. TEST CONDITIONS AND PROCEDURE

A. All evaluation tests were performed at room ambient pressure and temperature (25° C ± 2° C), with discharges at the 2-hour rate, and in accordance with reference (b), unless otherwise specified, and consisted of the following:

1. Phenolphthalein leak tests (2).

2. Three capacity tests, third at 20° C, with internal resistance measurements during the second charge/discharge test.

3. Charge retention test, 20° C.

4. Internal short test, 20° C.

5. Charge efficiency test, 20° C.

6. Overcharge tests, 0° and 35° C.

7. Phenolphthalein leak test.

(See Appendix II for summary of test procedure.)

II. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers (02800319-016 to 084 non-inclusive - L01), catalog number (42B006AB58-G1) and HAC's part number 259300. The cells were placed in temporary pack configurations for initial testing (Packs 555X and 556X). Each cell was individually restrained.

B. The 6.0 ampere-hour cell is rectangular with an average weight and physical dimensions as follows:

		Thickness (in.)			
			Pre-Test	Pre-Test	
Weight (g)	Height (in.)	Edge	Center	Center	Width (in.)
265.1	3.122	.902	.905	.910	2.134

C. The cell containers and covers are made of stainless steel. The positive terminal is insulated from the cell cover by a ceramic seal and protrudes through the cover as a solder-type terminal. The negative terminal is common to the cell's case and is a solder-type terminal.

III. RESULTS - The following was condensed from Tables I through V.

A. Measurements of the cell containers, following test, indicated an average increase of .005 inches in the plate stack thickness.

B. Average end-of-charge voltages and capacity output in ampere-hours (ah) were as follows:

Charge	Volts	ah Out
C/20 for 48 hrs @ 25° C	1.444	7.4
C/10 for 24 hrs @ 25° C	1.455	7.1
C/10 for 24 hrs @ 20° C	1.460	6.8
C/10 for 24 hrs @ 20° C*	1.458	6.0
C/40 for 20 hrs @ 20° C**	1.374	2.3
C/20 for 60 hrs @ 0° C	1.491	6.9
C/10 for 24 hrs @ 35° C	1.419	7.2

*Charge retention test
**Charge efficiency test, 3.0 ah input

C. The average internal resistance at the end-of-charge (Cycle 1) was 3.7 milliohms and during discharge (Cycle 2) it was 3.9 milliohms.

D. All cells exceeded the voltage requirement of 1.52 volts during the 0° C overcharge test although their end-of-charge voltages were below 1.50 volts. Peak voltages were 1.522 (S/N 084) to 1.534 volts (S/N 074).

E. The average cell voltage at the end of 1 week open-circuit-stand, during the charge retention test, was 1.312 volts.

F. The 24-hour average cell voltage following the 16-hour shunt period, during the internal short test, was 1.240 volts.

G. Following the initial evaluation tests, the cells were subjected to 21 cycles at 20° C in which the cells were discharged at 2.75 amperes for 1.2 hours and then charged at .60 amperes for 6.8 hours. At the end of 21 cycles, the cells were discharged at 2.75 amperes to .75 volts each cell. The end-of-discharge/charge voltages, of the last cycle, and the capacity output for each cell were as follows:

	Volts				Volts		
Serial No.	Discharge	Charge	ah Out	Serial No.	Discharge	Charge	ah Out
016	1.214	1.440	7.33	077	1.213	1.442	7.34
055	1.214	1.444	7.33	078	1.213	1.438	7.36
071	1.213	1.439	7.28	079	1.213	1.440	7.25
072	1.213	1.440	7.33	080	1.214	1.442	7.36
073	1.212	1.440	7.33	081	1.213	1.442	7.34
074	1.213	1.440	7.33	082	1.214	1.443	7.39
075	1.214	1.441	7.33	083	1.214	1.441	7.39
076	1.214	1.442	7.28	084	1.214	1.444	7.22

TABLE I

MEASUREMENT AND LEAK TEST DATA

SERIAL NUMBER	WEIGHT (Grams)	HEIGHT (Inches)	LENGTH (Inches)			WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS								
							INITIAL			POST HI VAC			POST TEST		
			MINIMUM *	MAXIMUM (Pre-Test)	MAXIMUM Post-Test)		Terminals		Other	Terminals		Other	Terminals		Other
							+	-		+	-		+	-	
076	265.2	3.125	.902	.912	.914	2.133									
055	265.3	3.119	.902	.907	.909	2.134									
071	263.9	3.119	.901	.903	.908	2.135									
072	264.2	3.136	.904	.906	.912	2.133									
073	265.0	3.126	.900	.902	.906	2.135									
074	265.3	3.119	.902	.907	.909	2.134									
075	264.8	3.121	.901	.902	.902	2.133									
076	265.1	3.120	.901	.908	.914	2.134									
077	265.6	3.130	.901	.902	.906	2.135	No	LEAKS		No	LEAKS		No	LEAKS	
078	264.4	3.126	.902	.913	.920	2.133									
079	265.4	3.115	.903	.900	.906	2.135									
080	265.6	3.119	.905	.902	.910	2.134									
081	265.5	3.119	.902	.912	.920	2.133									
082	265.2	3.124	.904	.898	.898	2.135									
083	266.5	3.117	.903	.898	.904	2.134									
084	264.5	3.116	.905	.915	.917	2.133									
* -	Minimum measurement taken at edge of case.														
-	Maximum measurement taken in center of case.														

TABLE II
Capacity Data

SERIAL NUMBER	Capacity Test 1						Capacity Test 2						Capacity Test 3 (20°C)					
	END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
	CELL (Volts)			CAPACITY (ah)			CELL (Volts)			CAPACITY (ah)			CELL (Volts)			CAPACITY (ah)		
016	1.445			7.4			1.455			7.1			1.460			6.8		
055	1.443			7.5			1.455			7.2			1.462			7.0		
071	1.443			7.3			1.451			6.9			1.456			6.7		
072	1.444			7.3			1.454			7.1			1.459			6.8		
073	1.445			7.4			1.454			7.1			1.459			6.9		
074	1.445			7.4			1.456			7.2			1.461			6.9		
075	1.445			7.4			1.455			7.1			1.460			6.7		
076	1.446			7.4			1.457			7.1			1.463			6.8		
077	1.444			7.4			1.456			7.2			1.461			6.9		
078	1.445			7.4			1.457			7.2			1.461			6.9		
079	1.444			7.3			1.453			7.0			1.458			6.8		
080	1.445			7.4			1.454			7.1			1.458			6.8		
081	1.446			7.4			1.457			7.1			1.462			6.8		
082	1.446			7.4			1.457			7.0			1.462			6.7		
083	1.447			7.4			1.457			7.1			1.461			6.8		
084	1.435			7.1			1.450			6.9			1.455			6.6		

SHD-HADC (SP 11/73)

NREC/C 79-224

TABLE III
INTERNAL RESISTANCE AND SHORT TEST DATA

9MD-NADC (8P 11/73)

SERIAL NUMBER	INTERNAL RESISTANCE (MILLIOHMS)			INTERNAL SHORT TEST		
	END-OF-CHARGE	ONE HOUR AFTER START-OF-DISCHARGE	TWO HOURS AFTER START-OF-DISCHARGE	AFTER 16 HR SHORT	AFTER 24 HOUR OCV STAND	
				CELL	CELL	
016	3.6	3.6	3.7	0.016	1.240	
055	3.6	3.7	3.8	0.010	1.236	
071	3.8	3.9	3.9	0.018	1.241	
072	3.7	3.7	3.9	0.016	1.244	
073	3.6	3.8	3.8	0.015	1.241	
074	3.7	3.8	3.8	0.015	1.240	
075	3.8	3.5	3.9	0.014	1.243	
076	3.6	3.7	3.9	0.014	1.240	
077	3.8	3.8	3.9	0.012	1.243	
078	3.8	3.7	3.8	0.012	1.242	
079	3.7	3.6	3.7	0.013	1.238	
080	3.8	3.7	3.9	0.013	1.239	
081	3.8	3.7	3.9	0.014	1.241	
082	3.5	3.8	3.9	0.014	1.240	
083	3.9	3.9	3.9	0.013	1.244	
084	3.6	3.8	3.9	0.016	1.232	

TABLE IV
CHARGE RETENTION TEST DATA

SERIAL NUMBER	END-OF-CHARGE			24 HR. OCV			1 WEEK OCV.			END-OF-DISCHARGE		
	CELL (VOLTS)			CELL (VOLTS)			CELL (VOLTS)			CAPACITY (AH)		
016	1.458			1.345			1.311			5.9		
055	1.460			1.347			1.312			6.2		
071	1.454			1.344			1.311			5.9		
072	1.457			1.344			1.311			6.0		
073	1.457			1.345			1.311			6.1		
074	1.459			1.346			1.312			6.1		
075	1.457			1.345			1.311			5.9		
076	1.460			1.347			1.312			5.9		
077	1.460			1.347			1.312			6.1		
078	1.460			1.348			1.313			6.0		
079	1.457			1.347			1.313			5.9		
080	1.456			1.346			1.312			6.0		
081	1.460			1.347			1.312			5.9		
082	1.459			1.345			1.312			5.8		
083	1.459			1.346			1.312			5.9		
084	1.453			1.345			1.312			5.8		

TABLE V
Charge Efficiency and Overcharge Data

SERIAL NUMBER	Charge Efficiency (20°C)						Overcharge Test (0°)						Overcharge Test (35°C)					
	END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
	CELL (Volts)			CAPACITY (ah)			CELL (Volts)			CAPACITY (ah)			CELL (Volts)			CAPACITY (ah)		
016	1.373			2.3			1.494			7.0			1.417			7.2		
055	1.375			2.2			1.493			7.2			1.420			7.3		
071	1.373			2.3			1.492			6.7			1.415			7.2		
072	1.374			2.3			1.492			6.9			1.415			7.1		
073	1.374			2.3			1.490			7.0			1.416			7.0		
074	1.375			2.2			1.490			7.1			1.416			7.0		
075	1.374			2.3			1.493			6.7			1.415			7.2		
076	1.374			2.4			1.492			7.0			1.418			7.2		
077	1.375			2.1			1.492			7.1			1.423			7.1		
078	1.374			2.3			1.490			7.0			1.425			7.2		
079	1.374			2.2			1.490			6.9			1.422			7.2		
080	1.374			2.2			1.489			6.9			1.421			7.2		
081	1.374			2.2			1.491			6.9			1.422			7.2		
082	1.375			2.3			1.490			6.8			1.418			7.2		
083	1.374			2.2			1.493			6.9			1.418			7.2		
084	1.373			2.3			1.492			6.7			1.417			7.2		

APPENDIX I

CELL DESCRIPTION

Cell History and Description

Sixteen 6AH cells were purchased by the GSFC, under Purchase Order Number S-53504-B and S-614478 from the General Electric Company. All cells were manufactured at the same time and from the same materials as the first lot of cells manufactured for HAC for the GOES-D, E, and F Program. These cells were manufactured in accordance with "Product Specification Hermetically Sealed Nickel-Cadmium Battery Cell-6AH-GOES," Hughes #PS 31999-013, Revision D. The General Electric Catalog Number is 42B006AB58. Some of the pertinent cell design features and manufacturing data are as follows:

Number of plates: 12 positive and 13 negative

Plate dimensions: positive: 2.060" x 1.968" x .024" nominal
negative: 2.060" x 1.968" x .0272" nominal

Negative plate is Teflon treated

Loading (Post #24018): positive: 10.59 gm/dm^2
negative: 12.30 gm/dm^2

KOH quantity (Lot #78109-31): 25 to 28cc of 31% KOH

Precharge: 1.58 AH

Separator: Pellon 2505

Interelectrode spacing: .008" nominal

Flooded cell tests: avg. positive 7.10AH
avg. negative 11.60AH

Single G.E. nickel-braze, ceramic-to-metal seal

Cell case (welded) dimensions: 2.789" x 2.131" x .890" nominal

Case wall thickness: .0165"

Height to top of terminals: 3.187" max

APPENDIX II

I. TEST PROCEDURE

A. Phenolphthalein Leak Tests:

1. This test is a determination of the condition of the welds and ceramic seals on receipt of the cells and following the last discharge of the cells (Cycle #7).

2. The cells were initially checked with a one-half of one percent phenolphthalein solution applied with a cotton swab and then placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. Upon removal they were rechecked for leaks and then received a final check following test completion. The requirement is no red or pink discoloration which indicates a leak.

B. Capacity Tests:

1. The capacity test is a determination of the cells' capacity at the C/2 discharge rate to 0.75 volt per cell, where C is the manufacturer's rated capacity. This type discharge follows all charges of this evaluation test.

2. The charges for the capacity tests are as follows:

a. C/20, 48 hours, room ambient (RA), Cycle 0, with a test limit of 1.52 volts or pressure of 100 psia.

b. C/10, 24 hours, RA, Cycle 1, with a test limit of 1.52 volts or 100 psia pressure and a requirement of maximum voltage (1.48) or pressure (75 psia).

c. C/10, 24 hours, 20° C, Cycle 2, with the same limits and requirements as the charge of Cycle 1.

C. Internal Resistance:

1. Measurements are taken across the cell terminals 1/2 hour before the end-of-charge (EOC) on Cycle 1, and 1 and 2 hours after the start-of-discharge of Cycle 2. These measurements were made with a Hewlett-Packard milliohmeter (Model 4328A).

D. Special Charge Retention Test, 20°C:

1. This test is to establish the capacity retention of each cell following a 7-day open-circuit-stand in a charge mode.

2. The cells are charged at C/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure. They then stand on open-circuit for 7 days, with the requirement that the open-circuit voltage of each cell, following this period, is within ±5 millivolts of the average cell voltage. The cells are then discharged and 80 percent capacity out of that obtained in Cycle 3 is required.

E. Internal Short Test:

1. This test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge, the cells are shunted with a 0.5-ohm, 3-watt resistor for 16 hours. At the end of 16 hours the resistors are removed and the cells stand on open-circuit-voltage (OCV) for 24 hours. A minimum voltage of 1.15 is required at the end of the 24 hours.

F. Charge Efficiency Test, 20° C:

1. This test is a measurement of the cells' charge efficiency when charged at a low current rate.

2. The cells are charged at C/40 for 20 hours with a test limit of 1.52 volts or 100 psia pressure. They are then discharged and the requirement is that the minimum capacity out equals 55 percent of capacity in during the preceding charge.

G. Overcharge Test #1, 0° C:

1. The purpose of this test is to determine the degree to which the cells will maintain a balanced voltage, and to determine the cells' capability to be overcharged without overcharging the negative electrode.

2. The cells are charged at C/20 for 60 hours. The test limits are cell voltages of 1.56 or greater for a continuous time period of 2 hours or pressures of 100 psia. The requirement is a voltage of 1.520 or a pressure of 75 psia. The cells are then discharged and 85 percent capacity out of that obtained in Cycle 3 is required.

H. Overcharge Test #2, 35° C:

1. This test is a measurement of the cells' capacity at a higher temperature when compared to its capacity at 20° C. This test also determines the cells' capability of reaching a point of pressure equilibrium; oxygen recombination at the negative plate at the same rate it is being generated at the positive plate.

2. The cells are charged C/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure and a requirement of 1.45 volts or 75 psia pressure. The cells are then discharged and 55 percent capacity out of that obtained in Cycle 3 is required.